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RESEARCH SAYS

Issues and Trends in Mathematics

Supporting ESL Students in Learning the Language of Mathematics

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Mathematics and Language

Mathematics can legitimately be considered as a language in itself in that it employs symbols to represent concepts and to facilitate our thinking about aspects of reality. However, mathematics is also intimately related to the natural language that we begin to acquire as infants and use to communicate in a variety of everyday and academic contexts. Mathematics and language are interconnected at several levels:

Teachers use natural language to explain mathematical concepts and carry out mathematical operations. Students who have limited proficiency in English require additional support in order to understand mathematical concepts and operations taught through English. Among the supports that teachers can use to make instruction comprehensible for English language learners are demonstrations, use of concrete hands-on manipulatives, graphic organizers, simplification and paraphrasing of instructional language, and direct teaching of key vocabulary.

As in other academic subjects, mathematics uses a specialized technical vocabulary to represent concepts and describe operations. As early as grade 1, students are required to learn the meaning of words such as *addition, subtraction, sum, addend,* and so on, that are likely to be found only in mathematics discourse. Other terms have specific meanings in mathematics discourse that differ from their meanings in everyday usage and in other subject areas. Examples include words such as *table, product, even, odd,* and so on. Homophones such as *sum* and *some* may also be confusing for ESL students. Grade 1 students are required to learn concepts such as *number facts* and *addition sentences* at a time when many of them (and particularly ESL students) may not know the broader meanings of words such as *facts* and *sentences*.

In addition to the technical vocabulary of mathematics, language intersects with mathematics at the broader level of general vocabulary, syntax, semantics, and discourse. Most mathematical problems require students to understand propositions and logical relations that are expressed through language. Consider this problem at the grade 4 level:

> *Wendy gave a total of 10 treats to her dogs. She gave her large dog 2 more treats than she gave her small dog. How many treats did she give to each dog?*

Here students need to understand (or be able to figure out) the meanings of words such as *total* and *treats*. They need to understand the logical relation expressed by the construction *more . . . than* and they need to infer that Wendy only has two dogs, although this is not expressed directly in the problem. Clearly, the language demands of the math curriculum increase as students progress through the grades and this can cause particular difficulties for ESL students.

The ESL Challenge

Numerous research studies have demonstrated that ESL students generally require at least five years to catch up to native speakers in academic language proficiency (e.g., reading and writing skills) (see Cummins, 2001 for a review). In mathematics, ESL students often make good progress in acquiring basic computation skills in the early grades; however, they typically experience greater difficulty in carrying out word problems, and this difficulty increases in the later grades of elementary schools as the word problems become more linguistically and conceptually complex.

These developmental patterns can be understood in relation to three very different aspects of language proficiency.

Conversational fluency is the ability to carry on a conversation in familiar face-to-face situations. This is the kind of proficiency that the vast majority of native speakers of English have developed when they enter school at age five. It involves use of high frequency words and simple grammatical constructions. ESL students generally develop basic fluency in conversational aspects of English within a year or two of exposure to the language either in school or in the environment.

Discrete language skills reflect specific phonological, lexical, and grammatical knowledge that students can acquire in two ways: (a) as a result of direct instruction and (b) both formal and informal practice (e.g., reading). Some of these discrete language skills are acquired early in schooling and some continue to be acquired throughout schooling. The discrete language skills acquired early include knowledge of the letters of the alphabet, the sounds represented by individual letters and combinations of letters, and the ability to decode written words into appropriate sounds. ESL students can learn these specific language skills at a relatively early stage in their acquisition of English; in fact, these skills can be learned concurrently with their development of basic vocabulary and conversational proficiency.

In mathematics, these discrete language skills include knowledge of the symbols that represent basic mathematical operations (e.g., +, –, etc.), the terms used to refer to these symbols and operations (add, subtract, plus, minus, etc.), and the basic technical vocabulary of mathematics. Clearly, the ability to decode written text is also a necessary (but not sufficient) condition for carrying out word problems expressed in written language.

Academic language proficiency includes knowledge of the less frequent vocabulary of English as well as the ability to interpret and produce increasingly complex written language. As students progress through the grades, they encounter far more low frequency words (primarily from Greek and Latin sources), complex syntax (e.g., passive voice), and abstract expressions that are virtually never heard in everyday conversation.

Students are required to understand linguistically and conceptually demanding texts in the content areas (e.g., literature, social studies, science, mathematics) and to use this language in an accurate and coherent way in their own writing.

Acquiring academic language is challenging for all students. For example, schools spend at least 12 years trying to extend the conversational language that native-speaking children bring to school into these more complex academic language spheres. It is hardly surprising, therefore, that research has repeatedly shown that ESL students usually require *at least* 5 years of exposure to academic English to catch up to native-speaker norms. In addition to internalizing increasingly complex academic language, *ESL students must catch up to a moving target.* Every year, native-speakers are making large gains in their reading and writing abilities and in their knowledge of vocabulary. In order to catch up to grade norms within 6 years, ESL students must make 15 months' gain in every 10-month school year. By contrast, the typical native-speaking student is expected to make 10 months' gain in a 10-month school year (Collier & Thomas, 1999).

All three aspects of language proficiency are important. However, they are frequently confused by policy-makers and the media. For example, it is sometimes claimed that children acquire language rapidly and that one-year of instructional support is sufficient to enable ESL students to catch up academically. In reality, many ESL students who have acquired fluent conversational skills are still a long way from grade-level performance in academic language proficiency (e.g., reading comprehension in content areas such as math).

Similarly, the learning of discrete language skills does not generalize automatically to academic language proficiency. ESL (and native-speaking) students who can "read" a mathematical problem fluently may have only a very limited understanding of the words and sentences they can decode.

Thus, ESL students may require extended language support within the classroom in order to continue to make grade level progress in content areas such as mathematics. Despite the fact that they have acquired conversational fluency in English together with basic mathematical vocabulary and computational skills, students may still experience gaps in their knowledge of more sophisticated vocabulary, syntax, and discourse features of mathematical language.

Teaching the Language of Mathematics

From an instructional perspective, the relationship between language and mathematics is two-way and reciprocal. Mathematical knowledge is developed through language and language abilities can and should be developed through mathematics instruction.

Because mathematical concepts and operations are embedded in language, the specialized vocabulary of mathematics and the discourse features of mathematical propositions must be taught explicitly if students are to make strong academic progress in mathematics.

Equally important however, is the fact that in teaching mathematics we are also developing and reinforcing students' general academic language proficiency. For example, think about the language learning that will likely occur as the teacher explains the following grade 1 problem to a group of ESL students:

> *Is 3 + 8 greater than 10, equal to 10,*
> *or less than 10? Explain.*

Students will learn not only the specific meanings of the terms *greater than, equal to,* and *less than,* but also synonyms for these terms (e.g., a synonym for *great* is *big* and the meaning of *greater than* is similar to the meaning of *bigger than).* The problem is also an opportunity for the teacher to teach students the general concept of *comparatives* and the general rule for forming comparatives (e.g., *great, greater, greatest; big, bigger, biggest).* The fact that not all comparatives take exactly this form can also be taught in relation to *less, lesser, least.* Finally, the meaning of the word *Explain* can be taught (e.g., *describe, tell about*, etc.) and related to its use in other subject areas (e.g., science).

The reciprocal interdependence of language and mathematics is very obvious from perusal of any mathematics textbook. Much of what students are expected to learn in mathematics is presented in written text. Students are required to read the text in order to develop their understanding of math concepts and carry out math problems. Frequently, they are also required to explain orally or in writing how they solved the problem. Obviously, teachers and students will discuss these concepts, but without strong reading skills, students will find it very difficult to acquire the content. Without strong writing skills, they will have difficulty demonstrating their knowledge of the concepts. Thus, effective reading and writing skills are necessary for students to make progress in mathematics, particularly as they progress through the elementary school grades. By the same token, the teaching of mathematics provides important opportunities for teachers to model academic language in their interactions with students and also to teach features of academic language directly (e.g., reading comprehension strategies, comparative adjectives, vocabulary, and so on).

Effective academic language instruction for ESL students across the curriculum is built on three fundamental pillars:

- Activate Prior Knowledge/Build Background Knowledge
- Access Content
- Extend Language

In developing mathematical knowledge through language, and language abilities through mathematics, we can apply these three instructional principles in powerful ways.

Activate Prior Knowledge/Build Background Knowledge

A. Prior knowledge as the foundation of learning. There is general agreement among cognitive psychologists that we learn by integrating new input into our existing cognitive structures or schemata. Our prior experience provides the foundation for interpreting new information. No learner is a blank slate. In fact, learning can be defined as the process of relating new information to the information we already possess. When we read a mathematical problem, for example, we construct meaning by bringing our prior knowledge of language, mathematics, and of the world in general to the text. Our prior knowledge enables us to make inferences about the meaning of words and expressions that we may not have come across before. As our prior knowledge expands through new learning, we are able to understand a greater range of mathematical concepts and also the language that expresses these concepts.

Thus, a major rationale for activating students' prior knowledge, or if there is minimal prior knowledge on a particular topic or issue, building it with the students, is to make the learning process more efficient. It is important to *activate* students' prior knowledge because students may not explicitly realize what they know about a particular topic or issue; consequently, their prior knowledge may not facilitate learning unless it is brought to consciousness.

B. Prior knowledge and ESL students. In a classroom with second language learners from diverse backgrounds, prior knowledge about a particular topic may vary widely. Thus, simple transmission of the information or skill will fail to connect with the prior knowledge and previous experience of many students. As a result, the input will be much less comprehensible for these students. Some students may have relevant information in their first language (L1) but not realize that there is any connection with what they are learning in English (L2). In other cases, the algorithms and strategies that students have acquired for carrying out math operations in their countries of origin may differ considerably from the procedures they are now being taught. Clearly, this discrepancy can cause confusion for students.

In teaching math to ESL students, it is important that we attempt to connect the instruction both with students' prior experience of learning math and with their knowledge of the world in general. In building up our knowledge of students' educational and cultural backgrounds, we can collaborate with ESL teachers who may have greater access to this information and also with community volunteers who can often provide invaluable insights about students' prior learning and cultural knowledge.

Lois Meyer (2000) has expressed clearly the importance of prior knowledge (familiarity with the topic) in reducing the cognitive load of the instruction for ESL students. She notes that the notion of *cognitive load* refers to the number and complexity of new concepts embedded in a lesson or text. This depends not only on the text itself but also on the students' prior knowledge of the content:

> If the English learner has little entry knowledge about the subject matter, the cognitive load of the lesson will be heavy, for many concepts will be new and unfamiliar. The student will have little basis from which to generate hypotheses regarding the meanings the teacher is conveying through English.
>
> If the student's entry knowledge of the topic is considerable, this will lighten the cognitive load. Learners can draw on their knowledge to interpret linguistic and non-linguistic clues in the lesson in order to make educated guesses about the meanings of the teacher's talk and text. (Meyer, 2000, p. 229)

Clearly, the cognitive load of many mathematical texts is considerable, particularly as students progress through the grades. Finding out what students know about a particular topic allows the teacher to supply relevant concepts or vocabulary that some or all students may be lacking but which will be important for understanding the upcoming text or lesson. Building this context permits students to understand more complex language and to pursue more cognitively demanding activities. It lessens the cognitive load of the text and frees up brain power.

C. Strategies for activating prior knowledge and building background knowledge. Three types of prior knowledge are relevant to consider in teaching mathematics:

Knowledge of math concepts and operations that students have previously been taught. For example, in grade 1 we might activate students' knowledge of counting as a prelude to teaching them to use counting on as a tool for addition. Or at the grade 4 level, we might activate students' knowledge of basic multiplication facts in order to reinforce the foundation for teaching more complex multiplication operations.

Knowledge of the world that students have acquired through their prior experiences. For example, at a very early age most children develop an intuitive sense of "fairness" and an ability to judge whether goods of various kinds (e.g., candies or treats) have been distributed equally or fairly. We can use brainstorming, role play, and simulation with concrete manipulatives to carry out a variety of math activities that tap into students' real-life experience of equal (or fair) distribution. Similarly, we can find out from students what activities they engage in outside of the school context and link mathematics instruction to those activities (e.g., students who engage in various sports can carry out a variety of calculations relevant to those sports, such as batting averages).

We can also be proactive in creating experiences for students that will promote mathematical knowledge and skill. For example, we might engage parents as collaborators by having them work with their children in calculating the proportion of weekly food expenditures that the family spends on the various food groups, thereby reinforcing both social studies and math concepts.

Knowledge of the world that students have acquired through secondary sources such as books, television, movies, and so on. For example, relatively few people in North America have ever been in a jungle, but most adults and children could describe the main features of jungles as a result of secondary experiences of various sorts. In the classroom, we can use literature, high interest expository texts, and other forms of media (e.g., videotapes) both to activate students' prior knowledge of math and also build background knowledge. In some cases, this will involve use of stories that have been specifically selected because they contain relevant math content; in other cases, we will connect math concepts and operations to other subject matter across the curriculum. For example, we might link math to a social studies unit on government and where it gets the funds to operate by having students calculate the sales tax that their families pay for various purchases.

We can also link math to the development of critical thinking by having students carry out projects that go beyond the curriculum in various ways. For example, in a class with many ESL students we might have students carry out a survey of the average number of languages that students in the class (or the entire school) know and how well they know these languages. In analyzing data that reflect their own experiences and identities, students' motivation to explore effective analytic strategies and presentation tools (e.g., graphs, computerized slide shows, and so on) is likely to be considerably greater than when the activities are more distant from their experiences and interests.

The essential point here is that the more connections we can make both to students' experiences and interests and to other areas of the curriculum, the more relevance math is likely to assume in students' minds and lives. This, in turn, will result in more powerful learning of math.

An additional consideration in activating ESL students' prior knowledge is that this process communicates a sense of respect for what students already know and an interest in their cultural background. This affirmation of students' identity increases students' personal and academic confidence and motivates them to invest their identities more strongly in pursuing academic success.

Access Content

How can teachers make the complex language of mathematics comprehensible for students who are still in the process of learning English? How can students be enabled to take ownership of their learning of math concepts and operations rather than just learning rote procedures? One important strategy has already been noted in the previous section. Activating and building students' background knowledge is an essential part of the process of helping students to participate academically and gain access to the meaning. When we activate students' prior knowledge we attempt to modify the soil so that the seeds of meaning will take root. However, we can also support or *scaffold* students' learning by modifying the input itself. We provide this scaffolding by embedding the content in a *richly redundant context* where there are multiple routes to the meaning in addition to the language itself.

The following list presents a variety of ways of modifying the presentation of mathematical content to ESL students so that they can more effectively get access to the meaning:

Demonstration/modeling. For example, teachers can take students through a word problem in math demonstrating step-by-step procedures and strategies in a clear and explicit manner.

Use of hands-on manipulatives, tools, and technology. In the early grades manipulatives may include counters and blocks that enable students to carry out a mathematical operation, literally with their hands, and actually see the concrete results of this operation. At more advanced levels, measuring tools such as rulers and protractors and technological aids such as calculators and computers will be used. The effectiveness of these tools will be enhanced if they are used within a project that students are intrinsically motivated to perform.

Whole class and small-group project work. Working either as a whole class or in heterogeneous groups or pairs, students can engage with real-life or simulated projects that require application of a variety of mathematical skills. Díaz-Rico and Weed (2002) give as an example a project in which students are told the classroom needs to be re-carpeted. They first estimate the area, then check their estimates with measuring tools. Working in groups, students could also calculate the cost of floor covering using prices for various types of floor covering obtained from local catalogues.

Use of visuals. We commonly hear the expression "A picture is worth a thousand words." There is a lot of truth to this in teaching academic content. Visuals enable students to "see" the basic concept we are trying to teach much more effectively than if we rely only on words. Once students have the concept, they are much more likely to be able to figure out the meaning of the words we use to talk about it. Among the visuals we can use in presenting math content are:

pictures/photographs, real objects, graphic organizers, drawings on overhead projectors or blackline masters, and so on. Graphic organizers are particularly useful because they can be used by teachers not only to present concepts but also by students themselves to take notes, organize their ideas in logical categories, and summarize the results of group brainstorming on particular issues. Some graphic organizers that are useful for teaching math are: *Venn Diagrams, Pie* and *Bar Charts, K-W-L Charts* (What we know, what we want to know, and what we have learned), *T-Charts* (e.g., for contrasts), *Problem/Solution Charts; Main Idea* and *Details Charts; Cause/Effect Charts; Sequence Charts, Time Lines,* and so on.

Language Clarification. This category includes a variety of strategies and language-oriented activities that clarify the meaning of new words and concepts. Teachers can modify their language to students by *paraphrasing ideas and explaining new concepts and words.* They can explain new words by providing synonyms, antonyms, and definitions either in English or in the home language of students, if they know it. Important vocabulary can be repeated and recycled as part of the paraphrasing of ideas. Teachers should speak in a natural rhythm but enunciate clearly and adjust speech to a rate that ESL students will find easier to understand. The meaning can also be communicated and/or reinforced through gestures, body language, and demonstrations.

Because of their common roots in Latin and Greek, much of the technical math vocabulary in English has cognates in Romance languages such as Spanish (e.g., addition – adición). Students who know these languages can be encouraged to make these cross-linguistic linkages as a means of reinforcing the concept. Bilingual and English-only dictionaries can also be useful tools for language clarification, particularly for older elementary grades students.

Dramatization/Acting Out. For beginning ESL students, *Total Physical Response,* where students act out commands, can be highly effective. Math calculations can be embedded in the commands that students act out. For example, students can progress from fully acting out the command *"Take five steps forward and two steps backward"* to calculating in their heads that they need only take three steps forward to reach the destination. Additionally, the meanings of individual words can be demonstrated through *gestures and pantomime.*

Extend Language

A systematic focus on and exploration of language is essential if students are to develop knowledge of the specific vocabulary and discourse patterns within the genre of mathematical language. As noted above, investigation of the language of mathematics can also develop in students a curiosity about language and deepen their understanding of how words work. Three strategies for extending students' knowledge of the language of mathematics are outlined below.

A. Creating mathematical language banks

Students can systematically collect the meanings of words and phrases they encounter in mathematical texts in a personal or group *language bank.* Ideally, the language bank would be created in a series of files within the classroom computer but it can also be done in a paper-and-pencil notebook.

Paradoxically, the complexity of mathematical language provides some important opportunities for language exploration. As mentioned above, a large percentage of the less frequent academic and technical vocabulary of English derives from Latin and Greek roots. One implication of this is that word formation follows some very predictable patterns. These patterns are similar in both English and Spanish.

When students know some of the rules or conventions of how academic words are formed, it gives them an edge in extending their vocabulary. It helps them not only figure out the meanings of individual words but also how to form different parts of speech from these words.

A central aspect of academic language is *nominalization.* This refers to the process whereby abstract nouns are formed from verbs and adjectives. Take, for example, four common verbs that occur in the math curriculum: *multiply, divide, measure,* and *equal.* The word families (excluding verb forms and plurals) for each of these words are presented below:

Verb	Noun	Adjective
multiply	multiplication multiple multiplicity	multiple
divide	division dividend	divisive divided
measure	measure measurement	measured
equal equalize	equality equal equalizer	equal equitable

We see in these four word families, several common ways in which the English language forms nouns from verbs. One pattern is to add the suffix *-tion* or *-ion* to the verb form as in *multiplication, division,* and many other mathematical terms such as *estimation, notation, operation,* and so on. Another pattern is to add the suffix *-ment* as in *measurement,* while a third pattern is to add the suffix *-ity* or *-ty* as in *equality, capacity, property*, and *probability.* When we demystify how this academic language works, students are more likely to recognize parts of speech in their reading of complex text across the curriculum and to become more adept at inferring meanings from context. For example, when a student recognizes that *acceleration* is a noun (rather than a verb or adjective) he or she has taken a step closer to the meaning of the term in the context of a particular sentence or text.

Students can be encouraged to use dictionaries (in both English and their L1 when available) to explore the more subtle meanings of these mathematical words. For example, they could be asked to work in pairs or small groups to work out the differences in meaning between *equal* and *equalize* (as verbs), *equality, equal,* and *equalizer* (nouns), and between *equal* and *equitable* (adjectives).

This nominalization process also permits us to think in terms of abstract realities or states and to use higher level cognitive functions that require uses of language very different from the conversational or "playground" language that we acquire in everyday situations. This point is made clearly by Pauline Gibbons:

> The playground situation does not normally offer children the opportunity to use such language as: *if we increase the angle by 5 degrees, we could cut the circumference into equal parts.* Nor does it normally require the language associated with the higher order thinking skills, such as hypothesizing, evaluating, inferring, generalizing, predicting or classifying. Yet these are the language functions which are related to learning and the development of cognition; they occur in all areas of the curriculum, and without them a child's potential in academic areas cannot be realized. (Gibbons, 1991, p. 3)

She goes on to point out that explicit modeling of academic language is particularly important in schools with large numbers of ESL students:

> In such a school it is very easy to fall into the habit of constantly simplifying our language because we expect not to be understood. But if we only ever use basic language such as *put in* or *take out* or *go faster,* some children will not have any opportunity to learn other ways of expressing these ideas, such as *insert* or *remove* or *accelerate*. And these are the words which are needed to refer to the general concepts related to the ideas, such as *removal, insertion* and *acceleration*. (1991, p. 18)

In short, when students know some of the rules or conventions of how academic words are formed, it gives them an edge in extending their vocabulary. It helps them not only figure out the meanings of individual words but also how to form different parts of speech from these words. One way of organizing students' language detective work in mathematics is to focus separately on *meaning, form,* and *use*. Working in pairs or small groups, students can be encouraged to collect and explore one mathematics word per day focusing on these categories.

Focus on meaning. Categories that can be explored within a Focus on Meaning include: *Mathematical meaning, Everyday meaning, Meaning in other subject areas, L1 equivalents, related words in L1 (cognates), synonyms, antonyms, homonyms, meaning of prefix, meaning of root, and meaning of suffix.* Not all of these categories will be relevant for every word but they provide a map of directions that an exploration of meaning might pursue. Take a possible exploration of the word subtract:

Mathematical meaning:	take one number or quantity from another
L1 equivalent (Spanish):	restar, sustraer
Synonym:	deduct
Antonym:	add
Meaning of prefix:	under or away
Meaning of root:	from the Latin for "pull"

Focus on form. Most of the root words in mathematics that come from Latin and Greek form not just one part of speech; we can make nouns, verbs, and adjectives from many of them. If we know the typical patterns for forming nouns and adjectives from these verbs, we can recognize these parts of speech when they appear in text. The implications for expanding students' vocabulary are clear: rather than learning just one word in isolation, students are enabled to learn entire *word families,* a process that can dramatically expand their working vocabulary.

Categories that can be explored within a Focus on Form include: *word family and grammatical patterns, words with same prefix, words with same root,* and *words with same suffix.* Consider again the word *subtract:*

Word family/ grammatical patterns:	subtract, subtracts, subtracted, subtracting (verb forms) subtraction, subtractions (noun forms)
Words with same prefix:	substitute, subtotal, suburban, subway, etc.
Words with same root:	tractor, traction

Focus on use. Students can explore the range of uses of particular words through brainstorming as a class or small group, looking words up in dictionaries, encyclopedias, or thesauri, or asking parents or other adults. Categories that can be explored within a Focus on Use include: *general uses, idioms, metaphorical uses, proverbs, advertisements, puns,* and *jokes*. For the word *subtract*, most students will not find much that will fall within these categories other than the category of *general use*. However, with some of the more frequent words in mathematical discourse that derive from the Anglo-Saxon lexicon of English rather than the Greek/Latin lexicon, many of these other categories will yield a multitude of examples. Consider the multiple meanings and figurative uses of words such as *great* (as in "greater than"), *big, double,* and so on. that students might explore.

In short, when students explore the language of mathematics by collecting specimens of mathematical language in a systematic and cumulative way, they expand not only their understanding of mathematical terms and concepts but also their knowledge of how the English language works (e.g., the fact that abstract nouns are often formed in English by adding *-tion* to the verb). The development of language awareness in this way will benefit students' reading comprehension and writing abilities across the curriculum.

B. Taking ownership of mathematical language by means of "reporting back"

If students are to take ownership of mathematical language, we must provide ample opportunities and encouragement for them to use this language for authentic purposes in the classroom. In the absence of active use of the language, students' grasp of the mathematical register is likely to remain shallow and passive.

Researchers (e.g., Swain, 1995) have noted three ways in which L2 acquisition is stimulated by active use of the language:

- Students must try to figure out sophisticated aspects of the target language in order to express what they want to communicate;
- It brings home to students and to their teachers what aspects of language they need assistance with;
- It provides teachers with the opportunity to provide corrective feedback to build language awareness and help students figure out how the language works.

One example of how this process operates in the teaching of content areas such as mathematics is provided by Gibbons (1991). She emphasizes the importance of reporting back as a strategy for promoting academic language development. For example, after a concrete hands-on group experience or project, students are asked to report back to the class orally about what they did and observed and then to write about it. As students progress from concrete hands-on experience to more abstract oral and written language use, they must include sufficient information within the language itself for the meaning to be understood by those who did not share in the original experience. She notes that:

> while hands-on experiences are a very valuable starting point for language development, they do not, on their own, offer children adequate opportunities to develop the more 'context-free' language associated with reading and writing. . . . a reporting back situation is a bridge into the more formal demands of literacy. It allows children to try out in speech—in a realistic and authentic situation—the sort of language they meet in books and which they need to develop in their writing. Where children's own language background has not led to this extension of oral language, it becomes even more important for the classroom to provide such opportunities. (1991, p. 31)

In short, students become more aware of the cognitive processes and strategies they use to solve math problems, and they are enabled to take ownership of the language that reflects and facilitates these cognitive processes, when the curriculum provides extensive opportunities for them to explain orally and in written form what they did and how they did it.

C. Mastering the language of mathematical assessment

High-stakes testing has become a fact of life in classrooms across the United States and consequently a large majority of curriculum materials include not only formative assessment integrated with the curriculum unit but also practice oriented to performance on state-wide standardized tests. Consistent with the emphasis on providing opportunities for students to take ownership of the language of mathematics through active use of that language, we can also encourage students to gain insight and control over the language of mathematical assessment. We can do this by having students create their own multiple-choice (or other relevant) tests in mathematics rather than always being on the receiving end of tests that adults have created. The process might work as follows:

> In order to familiarize students with the process (and also have some fun in a friendly competitive context), we can have them work in heterogeneous groups to construct their own tests, initially on topics with which they are familiar or on which they have carried out research. For example, the teacher might explain how multiple-choice items are constructed (e.g., the role of distractors) and each group might construct a set of approximately 5 items on topics such as baseball, popular music, television programs, popular slang, and so on. These items are then pooled and the entire set of items is administered to the entire class. Subsequently, each group might research aspects of a particular content area and construct items based on their research. In the context of math, groups could construct items that focus on the unit of study (e.g., fractions, decimals) that has just been completed. An incentive system could be instituted such that the groups gain points based on their performance on the pooled test that leads ultimately to some reward.

The rationale for this reversal of roles is that construction of test items is more cognitively challenging (and engaging) than simply performing test items. In order to come up with items that will be challenging for the other groups, students must know the content of the unit in an active rather than a passive way. The within-group discussion and collaboration in generating the items and distractors is also likely to reinforce both language and content knowledge for all students in the group, but particularly for those such as ESL students whose grasp of the content may be fragile.

Within this conception, standardized math tests are viewed as one particular genre of language. Students should be familiar with the conventions of this genre if their academic worth is to be recognized. In generating multiple-choice items, students are developing language awareness in the context of a highly challenging (but engaging) cognitive activity.

The same principle can be applied to the creation of other forms of assessment that tap both math and language concepts. For example, we could have students create multiple-choice cloze sentences that reflect both everyday and math-specific meanings of mathematical vocabulary.

Target words: plus double equals negative

1. *Five ________ six _________ eleven;*
2. *On the ________ side, my share _________ his.*
3. *On the ________ side, his share is _________ mine.*
4. *Numbers less than zero are called _________ numbers.*
5. *When we multiply by two, we _______ the quantity.*

Conclusion

Mathematics will assume relevance to students and be learned much more effectively when students can relate the content to their prior experience and current interests. In addition to activating students' prior knowledge and building background knowledge, we may need to modify our instruction in specific ways to make the content accessible to ESL students who are still in the process of catching up to native-speakers in academic English language proficiency. This catch-up process will typically take at least five years, partly because students are catching up to a moving target—native-speakers of English are not standing still waiting for ESL students to bridge the gap. Thus, even ESL students who are relatively fluent in English may require specific support in accessing mathematical concepts and problems expressed through English. These supports should focus not only on making the mathematics content comprehensible to students but also on extending their awareness of how the language of mathematics works. In this way, students can develop insights about academic language that will bear fruit in other content areas (e.g., reading comprehension in language arts, vocabulary building in social studies). A goal of this process of extending students' command of academic language is to enable them to take ownership of the language of the curriculum and use it for authentic purposes. Thus, they will benefit from opportunities to carry out projects and explain what they did both orally and in written form. As the audience becomes more distant (e.g., in the case of a more formal written report) students are required to use more abstract, explicit, and precise language to communicate their meaning. When we integrate these active uses of language with the mathematics curriculum, students benefit both with respect to mathematics and language abilities.

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